Figure 2(a). CNR (dB) vs Distance from Center of Cell (meters) (1° mainbeam tilt angle)

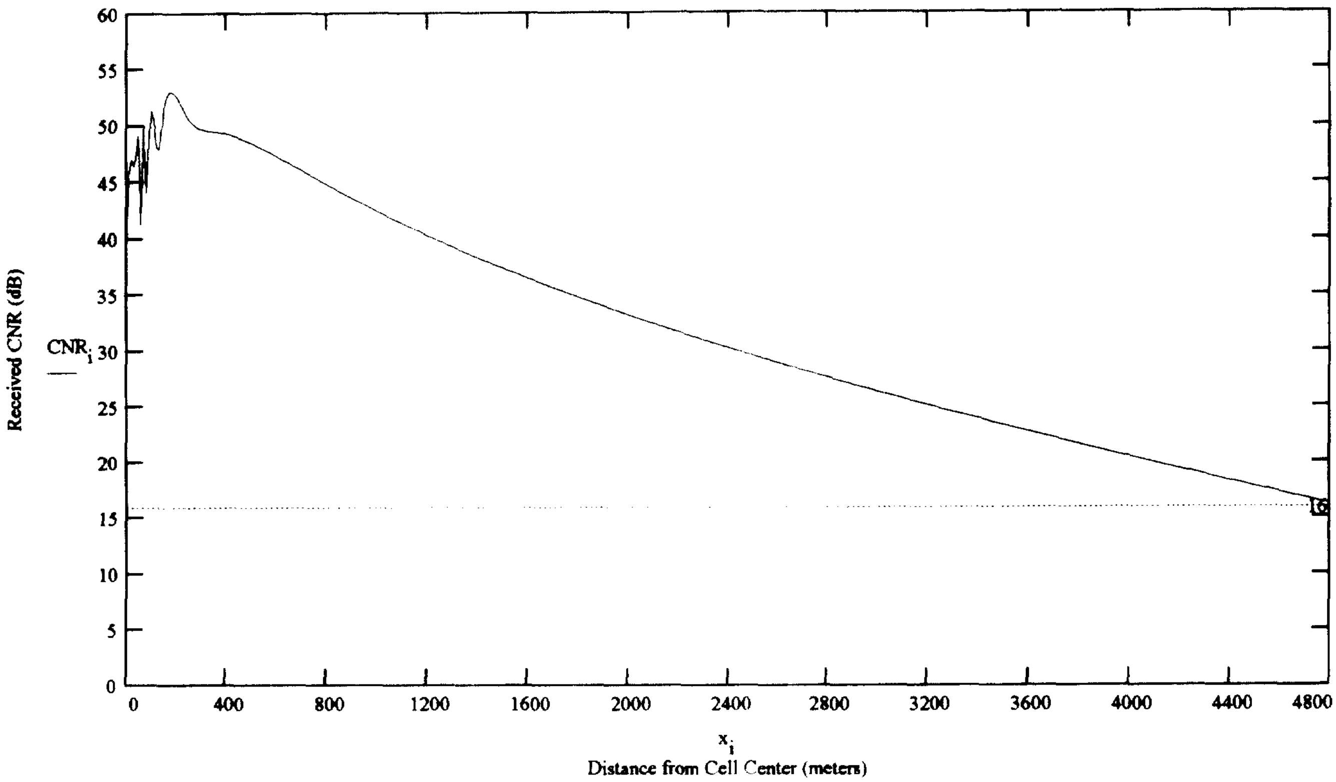


Figure 2(b). Transmit Hub Antenna Gain of Sectoral Horn Antenna vs Distance from Cell Center (1° tilt)

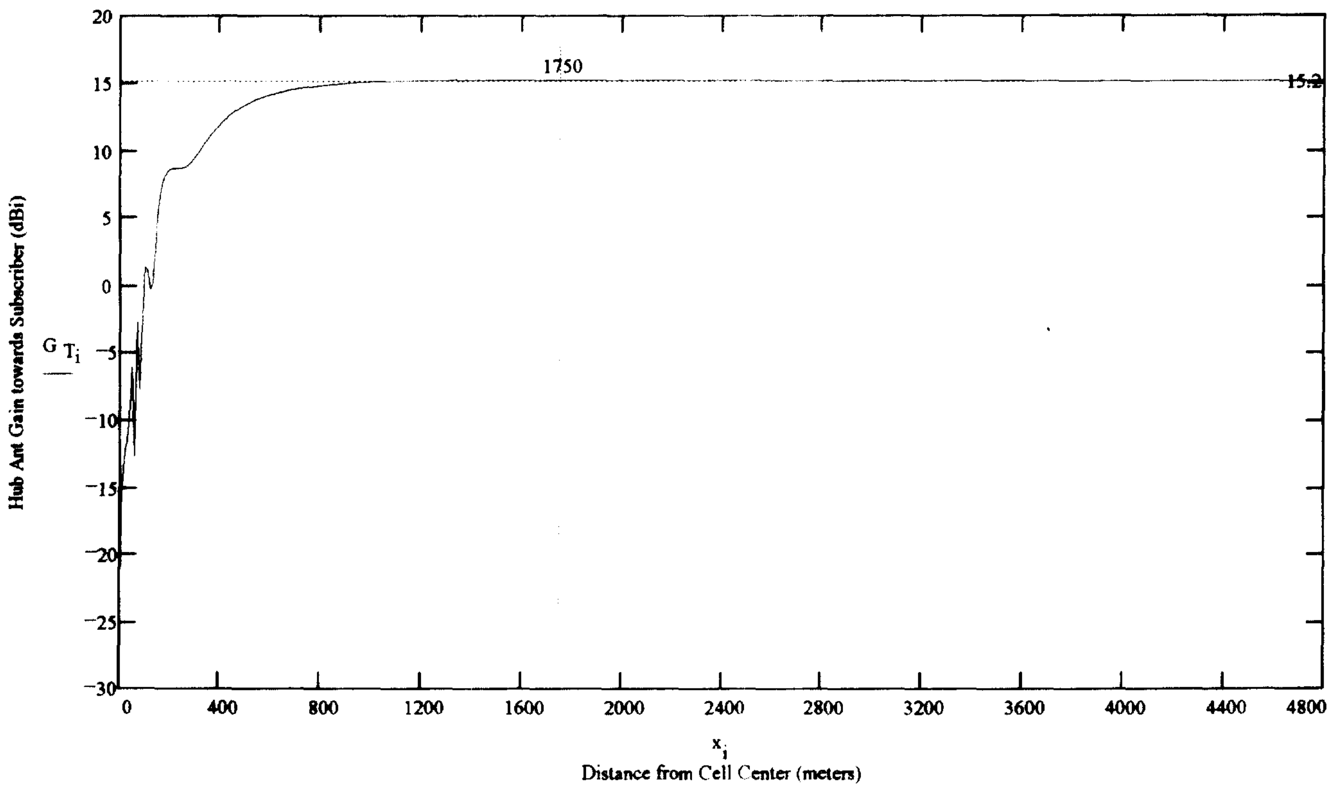


Figure 2(c). Off-axis Angle of Subscriber from Hub Antenna Mainbeam Axis vs Subscriber Distance from Cell Center

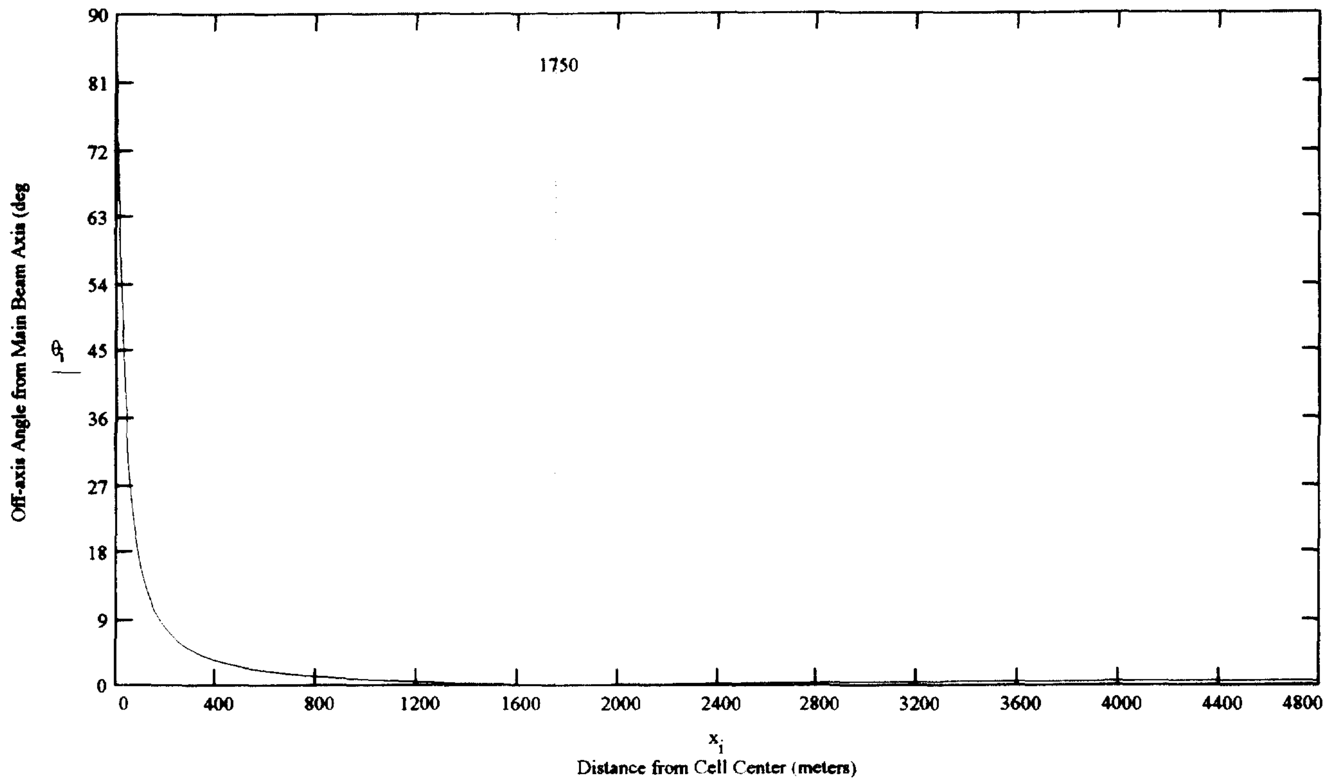
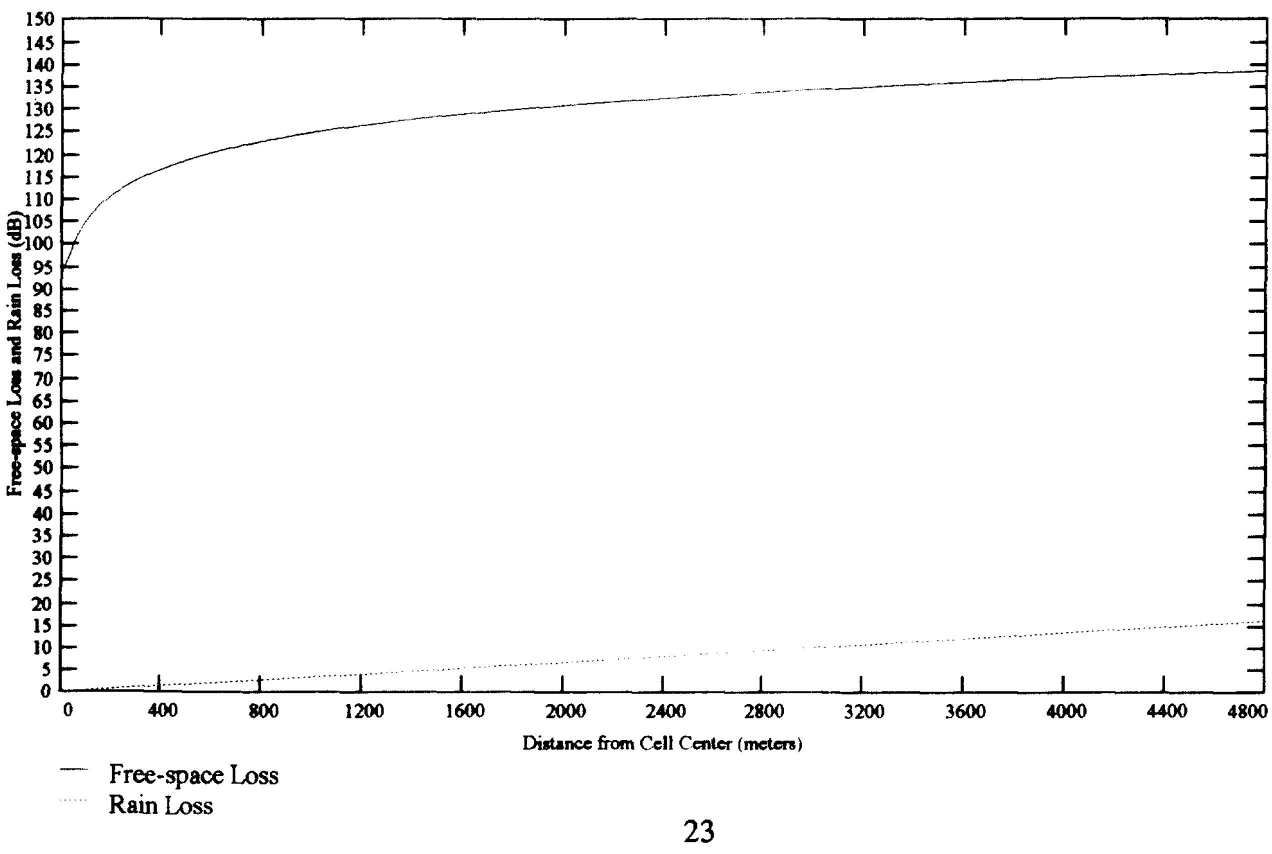


Figure 2(d). Free-Space Loss and Rain Loss vs Distance from Cell Center



APPENDIX B

Reflection Properties at 28 and 41 Ghz

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LMDS - Reflection Properties at 28 and 41 GHz

Analytical studies, supplemented by laboratory measurements, have been performed at NASA Lewis to determine the variation in reflection properties between the 28 and 41 GHz frequency bands.

The analytical and experimental results both indicate that the reflection of incident signals by various building materials varies greatly based upon the type of material, the thickness of the material, and the angle of incidence, as well as frequency. However, the interaction of these parameters are such that cumulatively there is no significant difference in reflection properties between the two frequency bands that would result in a measurably superior performance of an LMDS system at one band compared to the other.

The results of the analysis and measurements are summarized by the following tables and plots.

CALCULATED RESULTS

Figures 2 through 5 are plots of the calculated reflection coefficients for glass and plywood of several thicknesses.

Figure 2 plots the reflection coefficient for 0.125 inch thick glass at 28.5 and 41.5 GHz. Below 45°, the reflection coefficient is higher at 28.5 GHz, while above 45° the reflection coefficient is higher at 41.5 GHz.

Figure 3 plots the reflection coefficient for 0.625 inch thick plywood at 28.5 and 41.5 GHz. The reflection coefficient is higher at 28.5 GHz for reflection angles of between 20° and 45°, and above 56°. At all other reflection angles, the reflection coefficient is higher at 41.5 GHz.

The difference between reflection coefficients for the above cases is plotted in Figure 4.

Figure 5 plots the reflection coefficient as a function of frequency for three different thicknesses of glass and plywood. The plots indicate considerable variability as a function of frequency, material, and material thickness.

MEASURED RESULTS

Figure 1 shows the laboratory test setup for a set of reflection measurements performed on four material: metal (aluminum sheet), concrete brick, wood(composite of 0.5 inch plywood and 1 inch by 2 inch cross pieces), and mirror (0.125 inch silvered glass)). The reflection coefficient was measured for incident angles of 10°, 30°, 45°, and 60°.

The test results are summarized in Tables I and II. In table I, the measured reflection coefficients are given, where the reflection coefficient is calculated for the brick, wood, and mirror by comparison to the results for metal. The metal, approximating a perfect conductor, is used as a system calibration. The results are given for frequencies of 28.5 and 39.0 GHz (due to instrumentation limitations, results at 41.5 GHz could not be obtained.)

In table II, the difference between the measured results obtained at 28.5 and 39.0 GHz is listed. A positive number indicates a higher reflection coefficient at 28.5 GHz, while a negative number indicates a higher refection coefficient at 39.0 GHz. The results indicate the variation in reflection properties between the two frequencies resulting from different materials and reflection angles. Of the 12 cases presented, the reflection coefficient is higher at 28.5 GHz in 6 instances. The average for the 12 cases is -0.68 dB, or a slightly higher average reflection at 39.0 GHz.

Limitations in laboratory instrumentation and available materials for testing, as well as for time to complete the measurements make a direct comparison between the measured and calculated results difficult.

Figures 6 through 14 give a comparison of the uncorrected measured results, plotted as a function of frequency, with the calculated results. Please note differences in the horizontal (frequency) scale between the measured and calculated data. Figures 6 - 8 show measured data for mirror and wood and calculated data for glass and plywood, at an incident angle of 10°. Figures 9 - 11 show measured data for mirror and wood and calculated data for glass and plywood, at an incident angle of 30°. Figures 12 - 14 show measured data for mirror and wood and calculated data for glass and plywood, at an incident angle of 60°. Taking into account the difference in conditions between measured and calculated cases, the plots in figures 6 - 14 show general agreement between the measured and calculated results in terms of the variation of reflection coefficient with frequency.

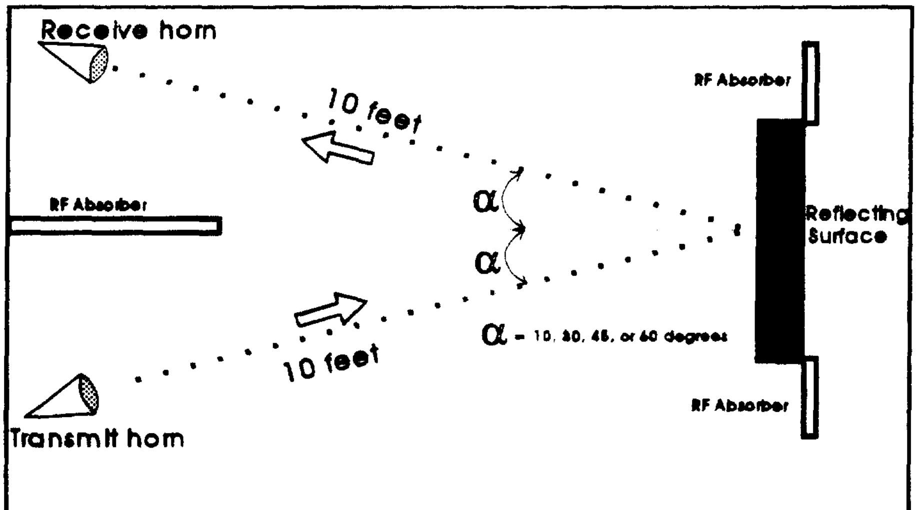


Figure 1 - Laboratory Test Configuration

TABLE I
Measured Reflection Coefficient at 28.5 and 39.0 GHz
for Several Building Materials

REFLECTION ANGLE	REFLECTION COEFFICIENT [DB] **BRICK**		REFLECTION COEFFICIENT [DB] **WOOD**		REFLECTION COEFFICIENT [DB] **MIRROR**	
	28.5 GHz	39.0 GHz	28.5 GHz	39.0 GHz	28.5 GHz	39.0 GHz
10°	-11.5	-15.8	-16.5	-11.1	-3.1	-0.6
30°	-10.3	-7.7	-12.8	-12.2	-0.5	-2.3
45°	-13.6	-5.2	-15.1	-17.3	-3.2	-2.7
60°	-4.3	-4.4	-13.1	-14.5	-0.7	-2.8

TABLE II
Difference between received reflected power
at 28.5 GHz and 39.0 GHz

INCIDENT ANGLE	REFLECTED POWER DELTA (dB) **BRICK**	REFLECTED POWER DELTA (dB) **WOOD**	REFLECTED POWER DELTA (dB) **MIRROR**
10 Degrees	4.3	-5.4	-2.5
30 Degrees	-2.6	-0.6	1.8
45 Degrees	-8.4	2.2	-0.5
60 Degrees	0.1	1.4	2.1

The delta shown in the chart is derived by subtracting the calibrated received power at 39.0 GHz from the calibrated received power at 28.5 GHz. A positive value indicates a higher received power at 28.5 GHz; a negative value indicates a higher received power at 39 GHz.

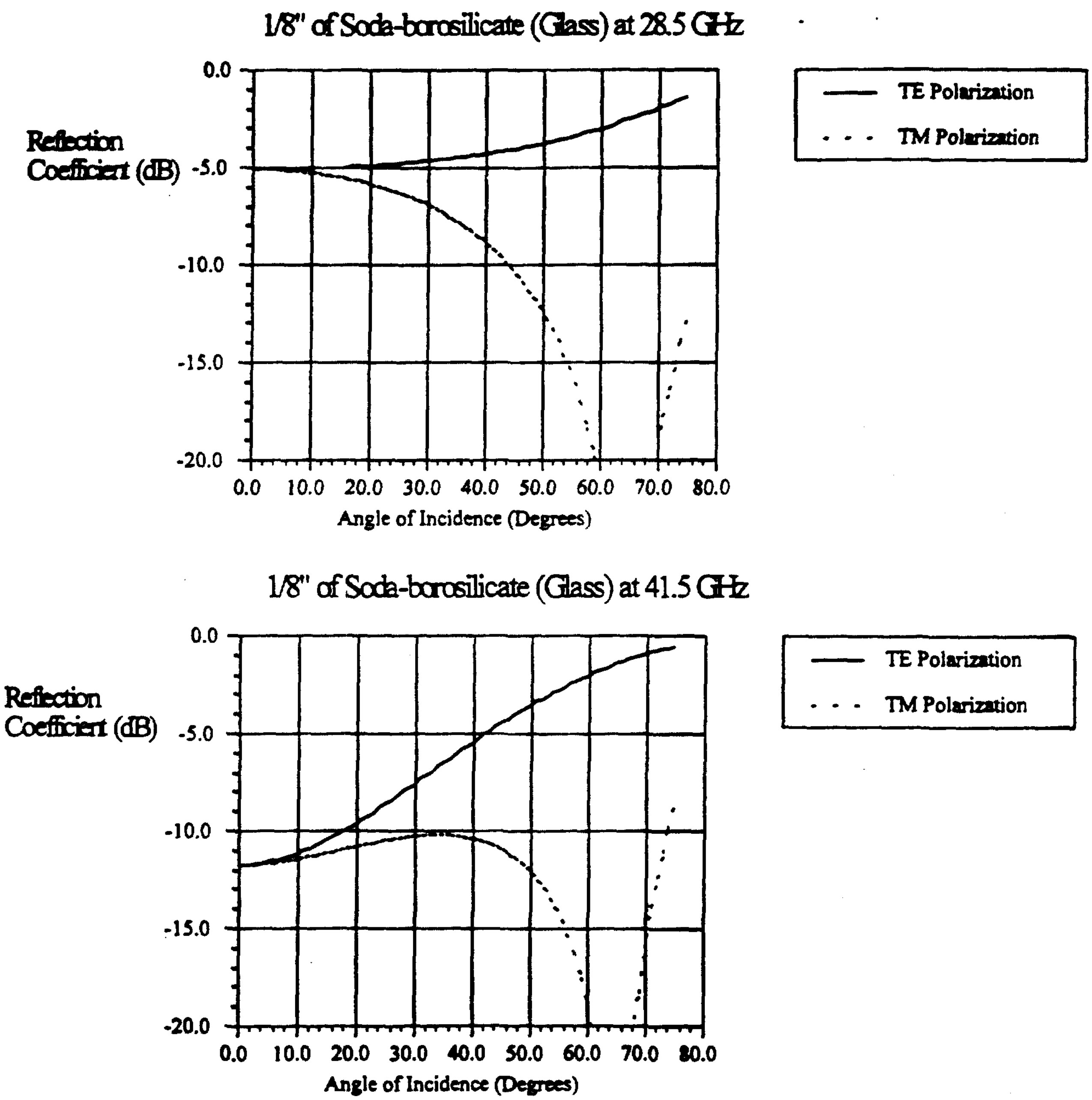


Figure 2. Theoretical Reflection Coefficient of a Type of Glass.

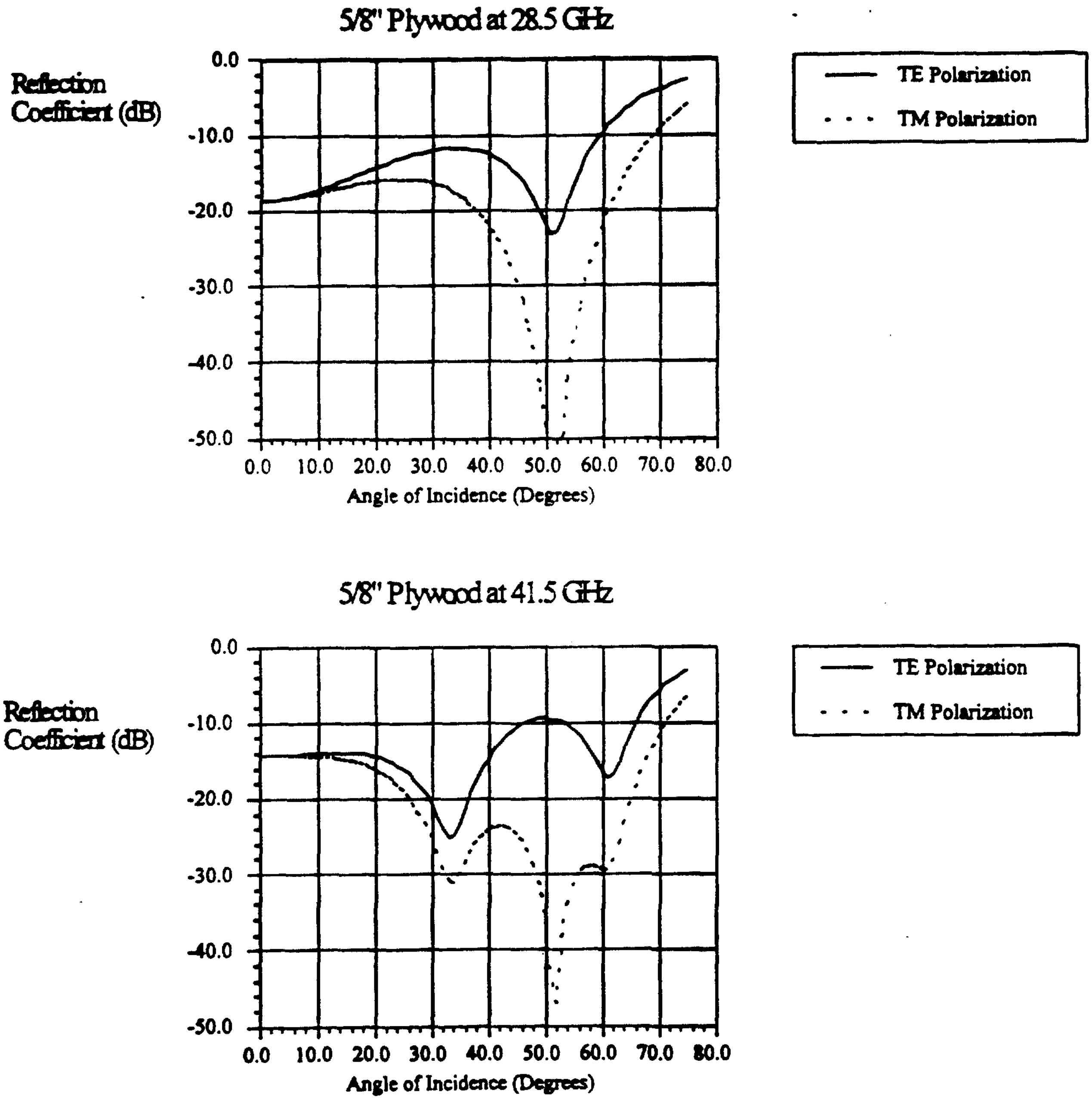
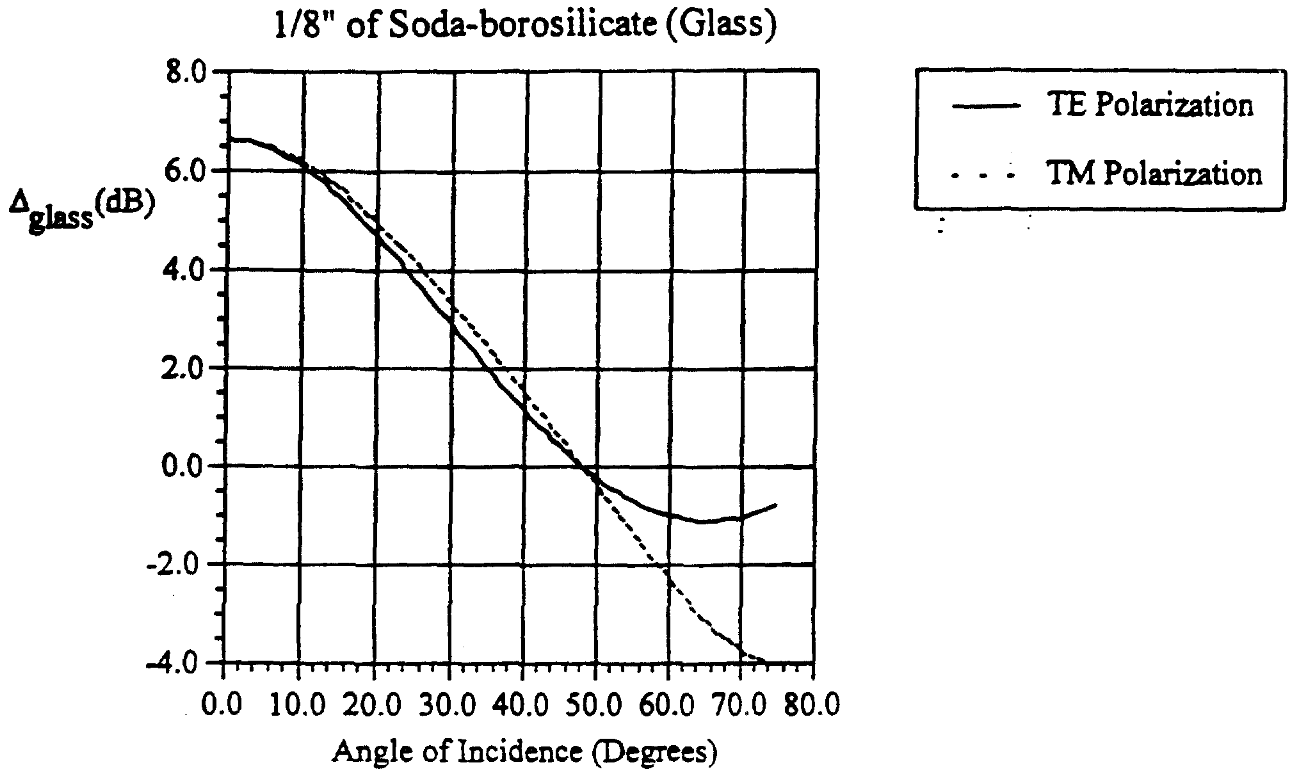


Figure 3. Theoretical Reflection Coefficient of Plywood.



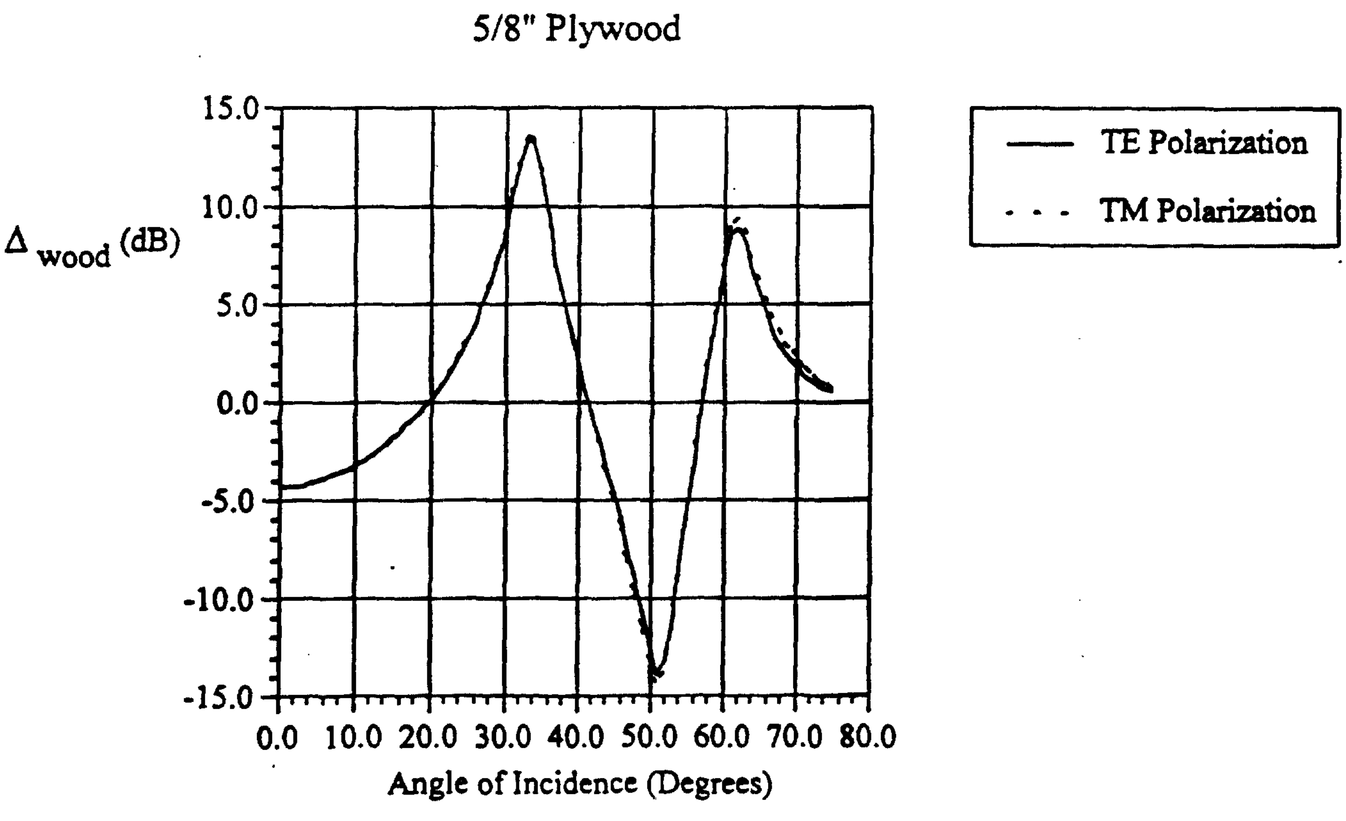
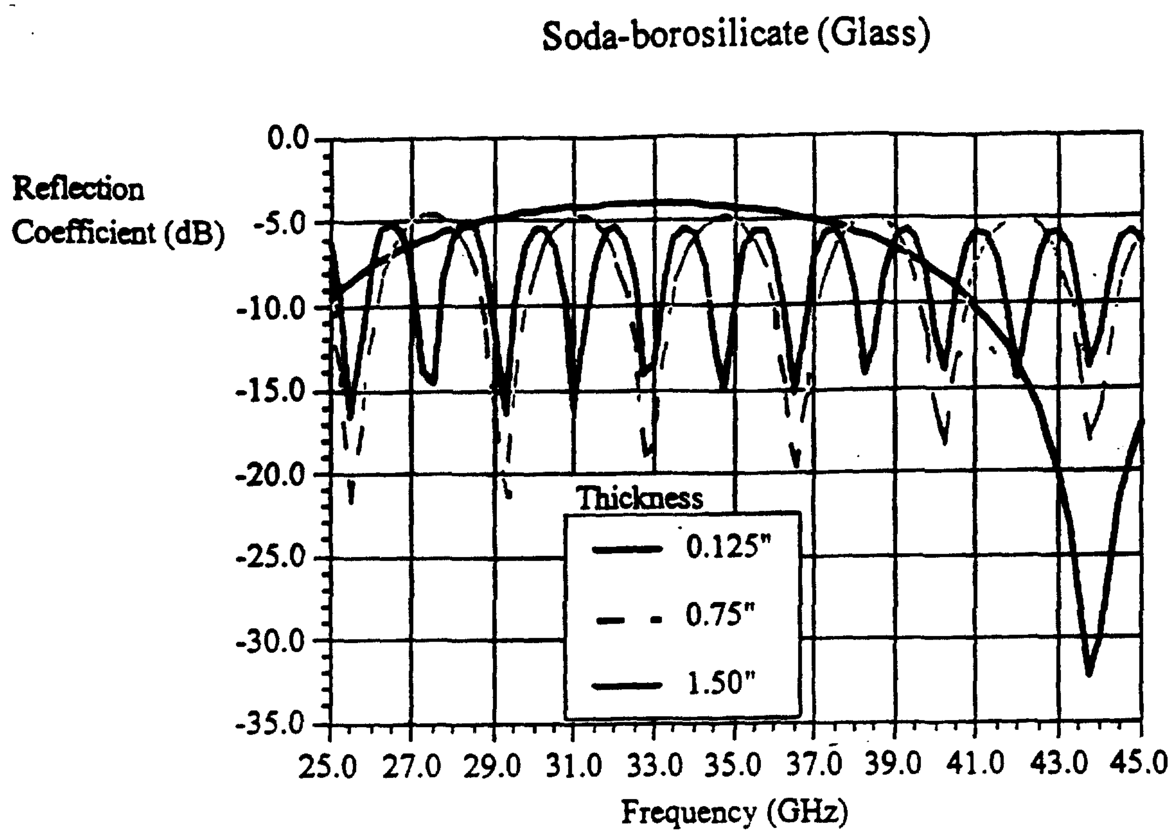


Figure 4. Change in Reflection Coefficient at 28.5 GHz -vs- 41.5 GHz.



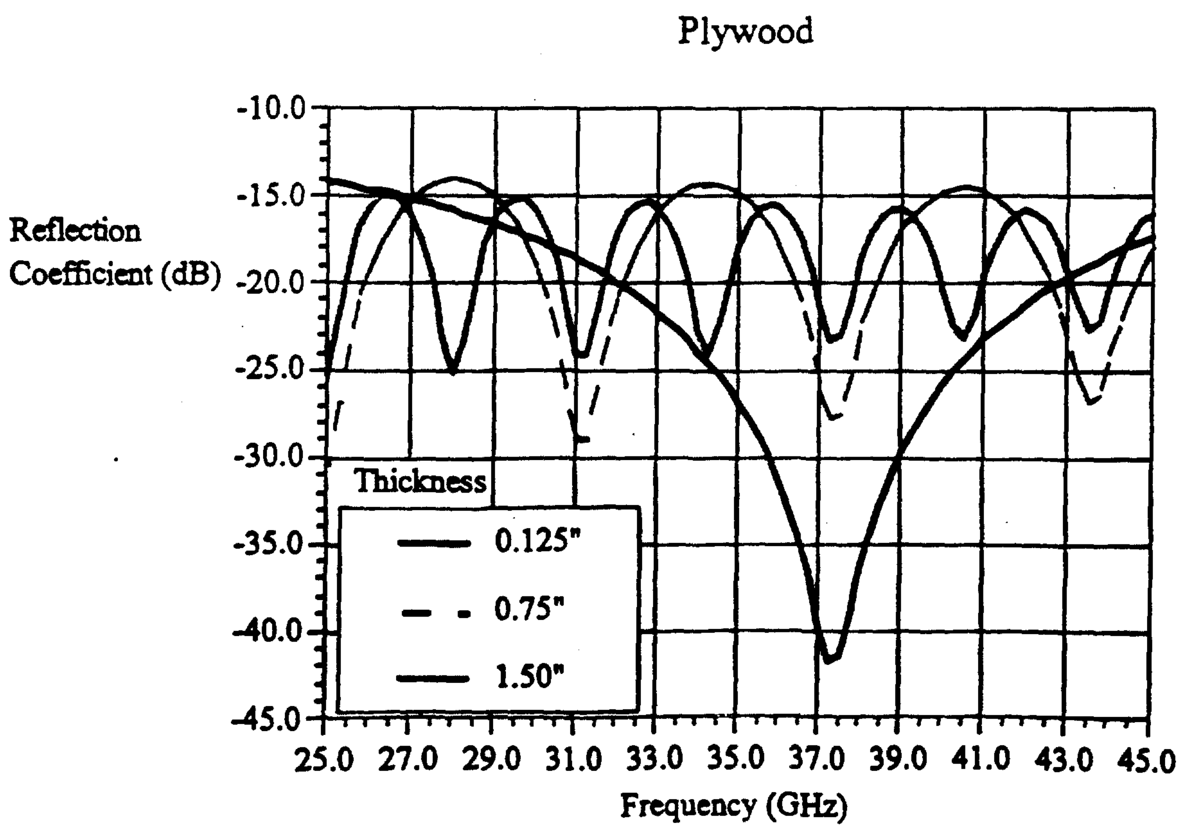


Figure 5. Reflection Coefficient as a Function of Material Thickness and Frequency. Zero Degree Angle of Incidence.

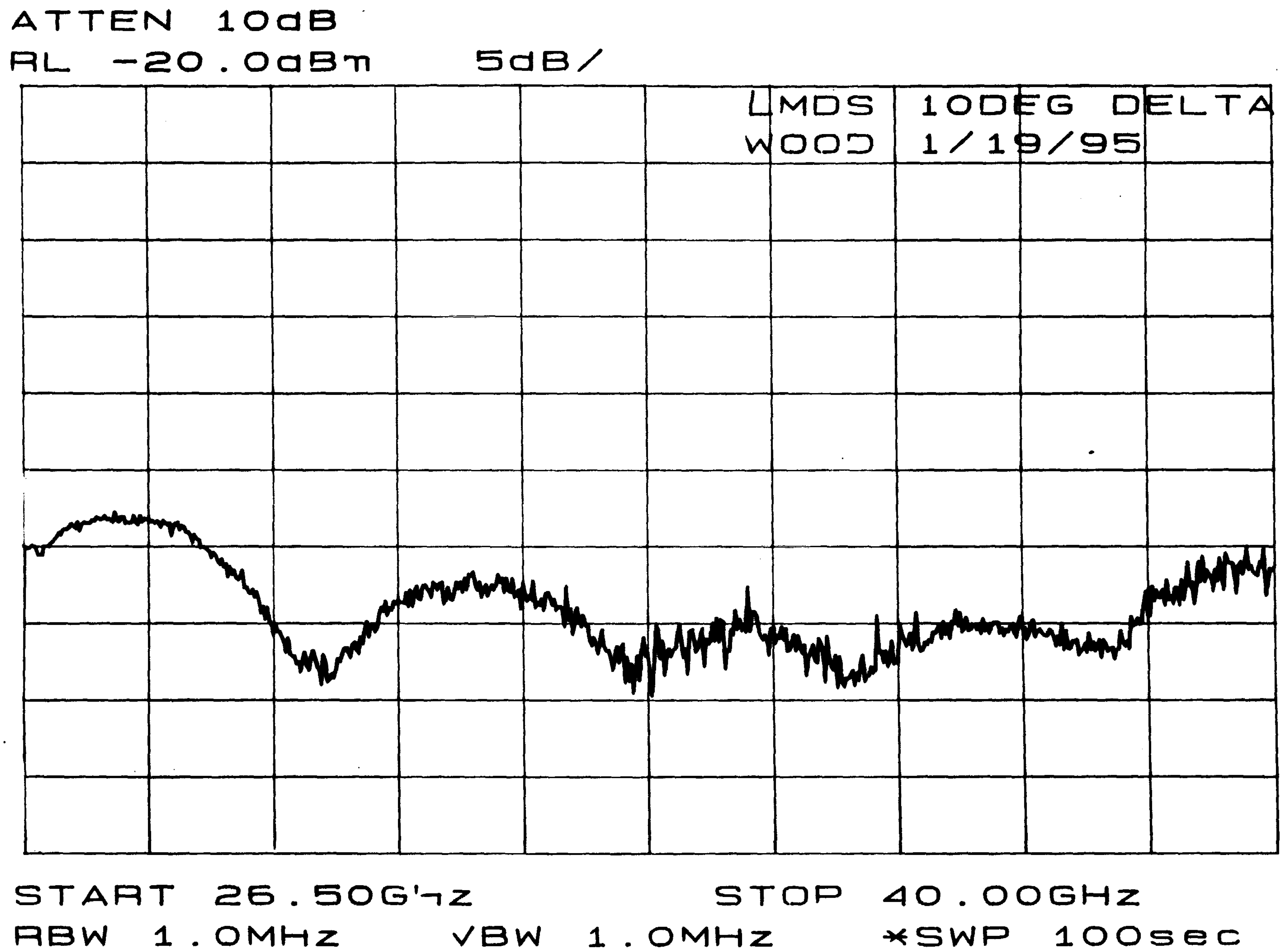


Figure 6. Measured reflection for wood at a 10° incident angle.

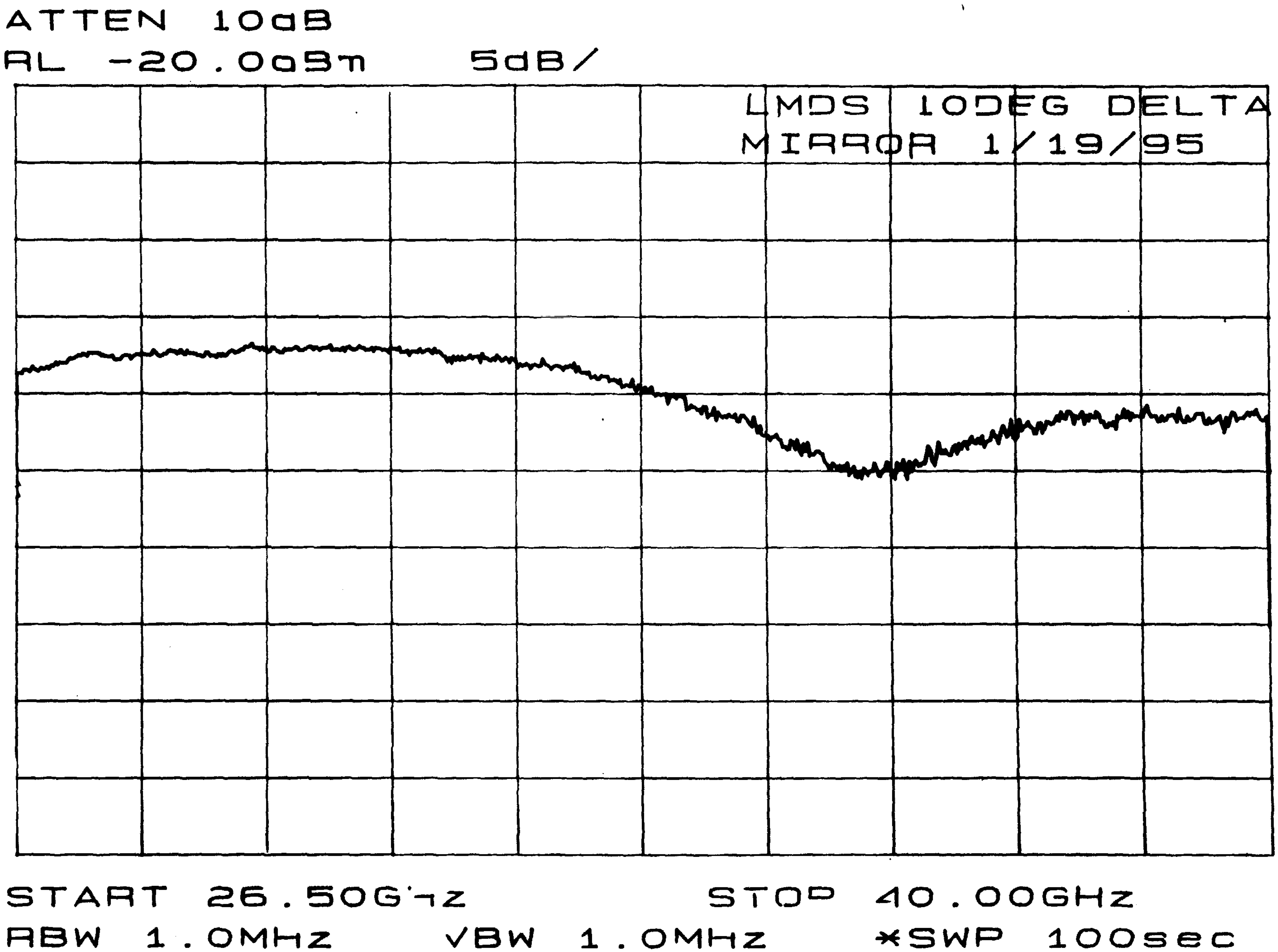


Figure 7. Measured reflection for mirror at a 10° incident angle.

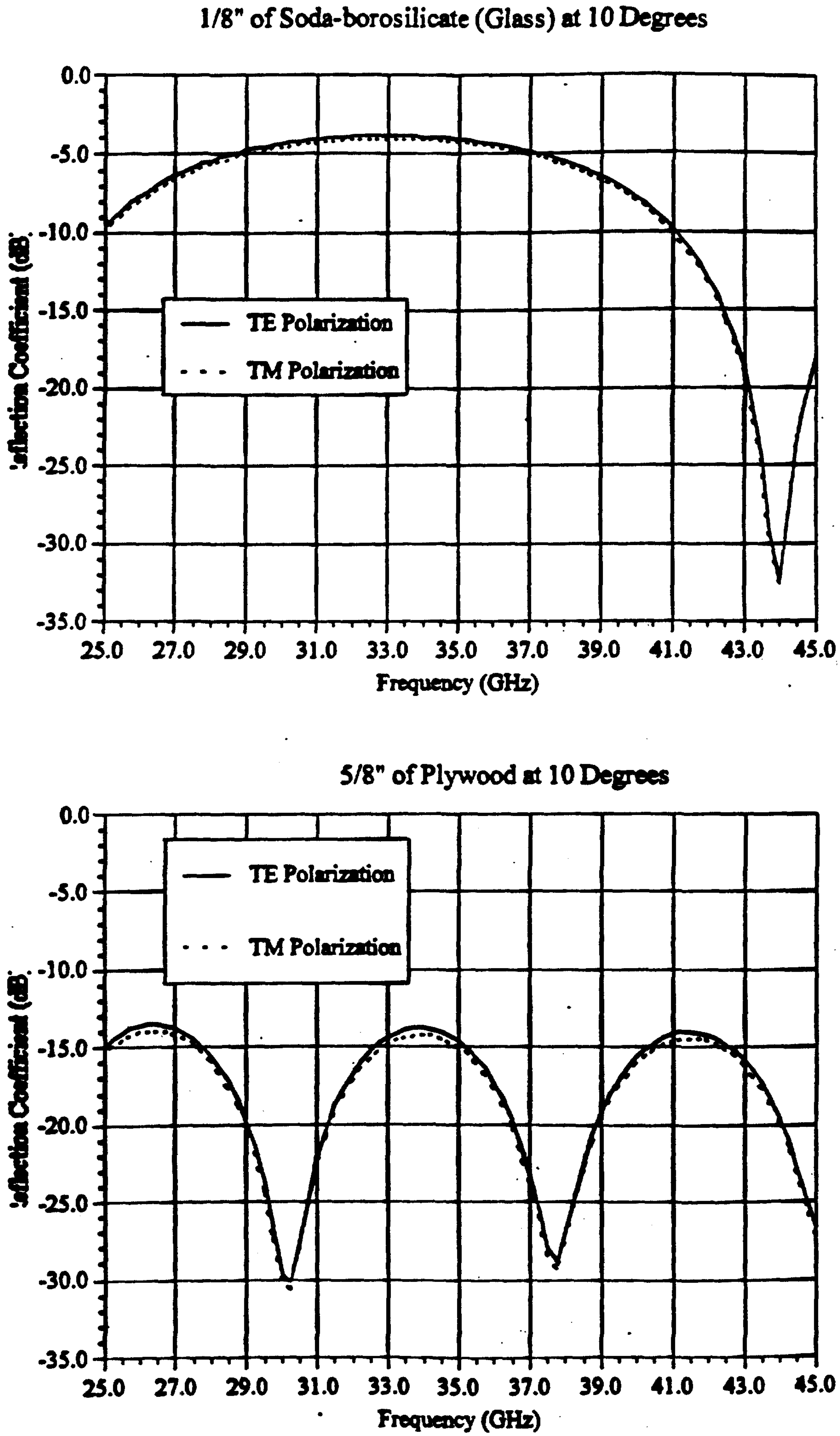


Figure 8. Calculated reflection coefficient for glass and wood at a 10° incident angle.

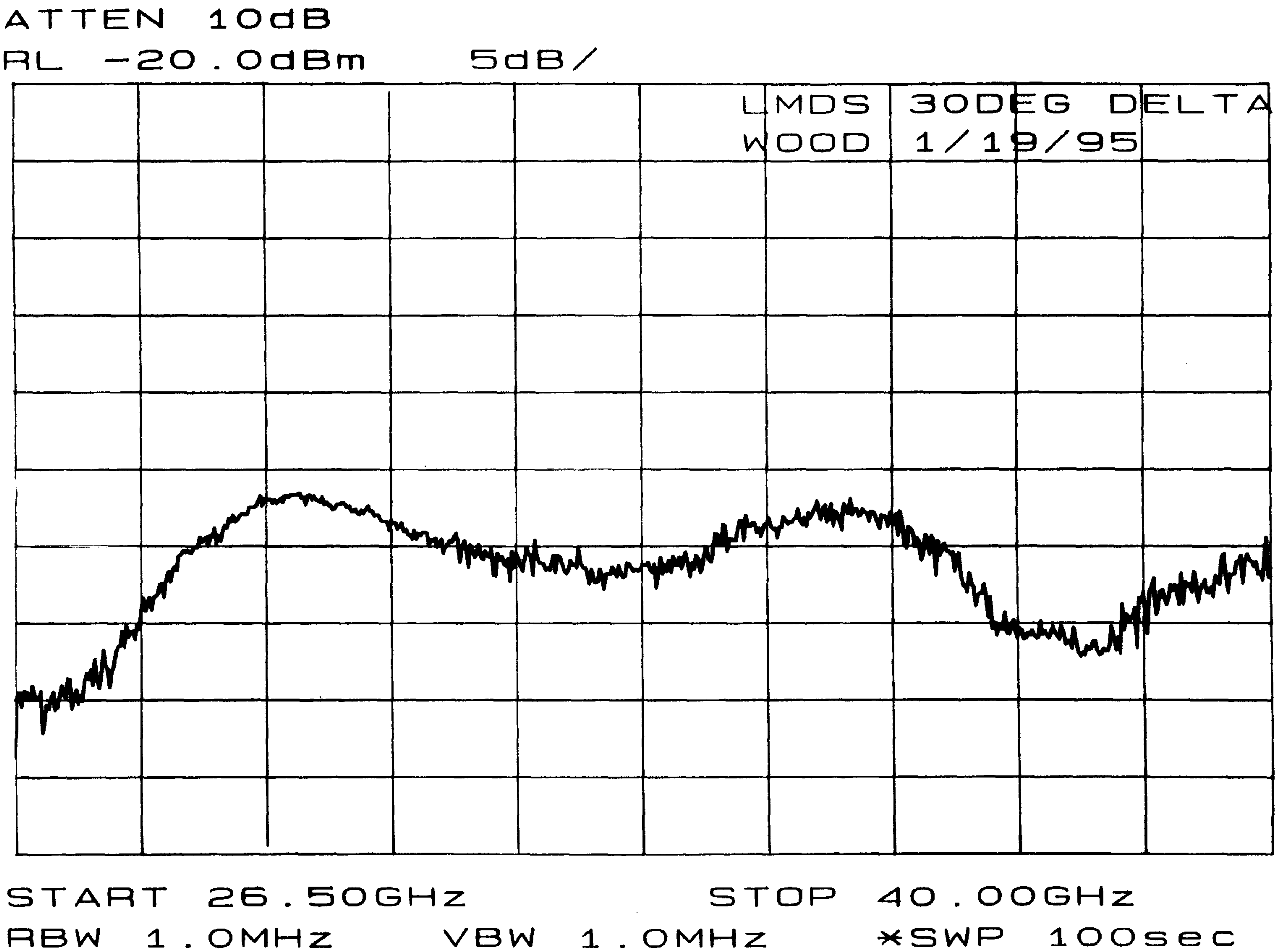


Figure 9. Measured reflection for wood at a 30° incident angle.

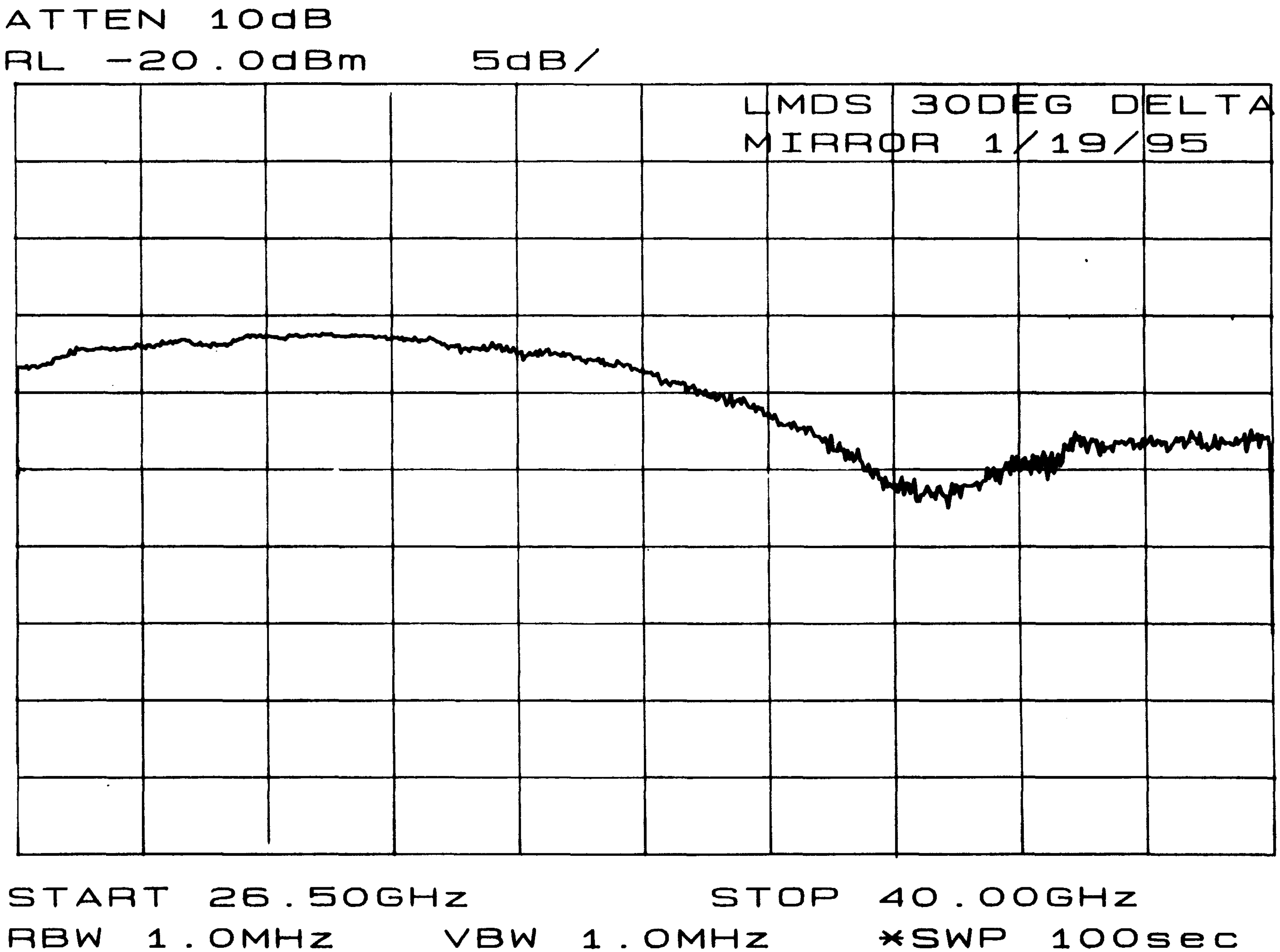
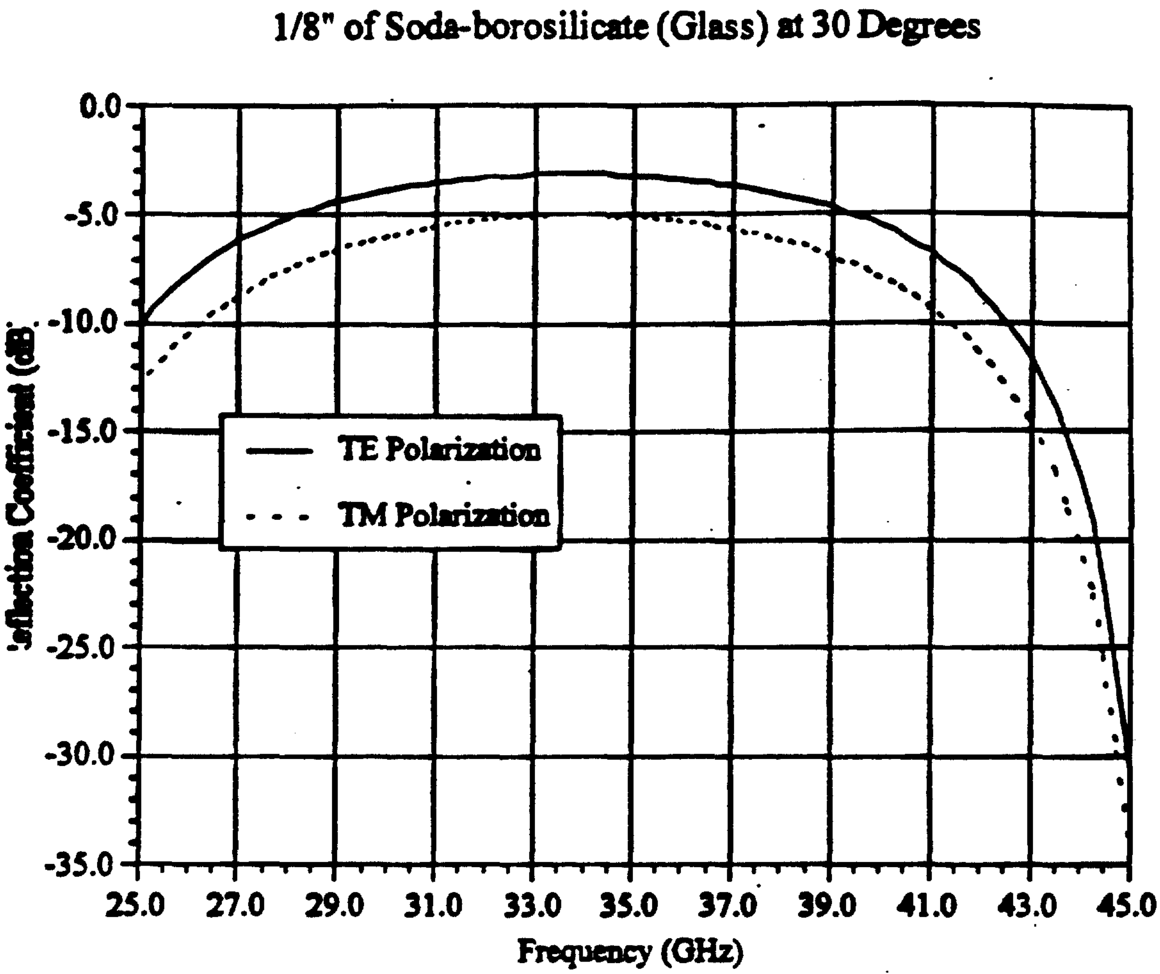
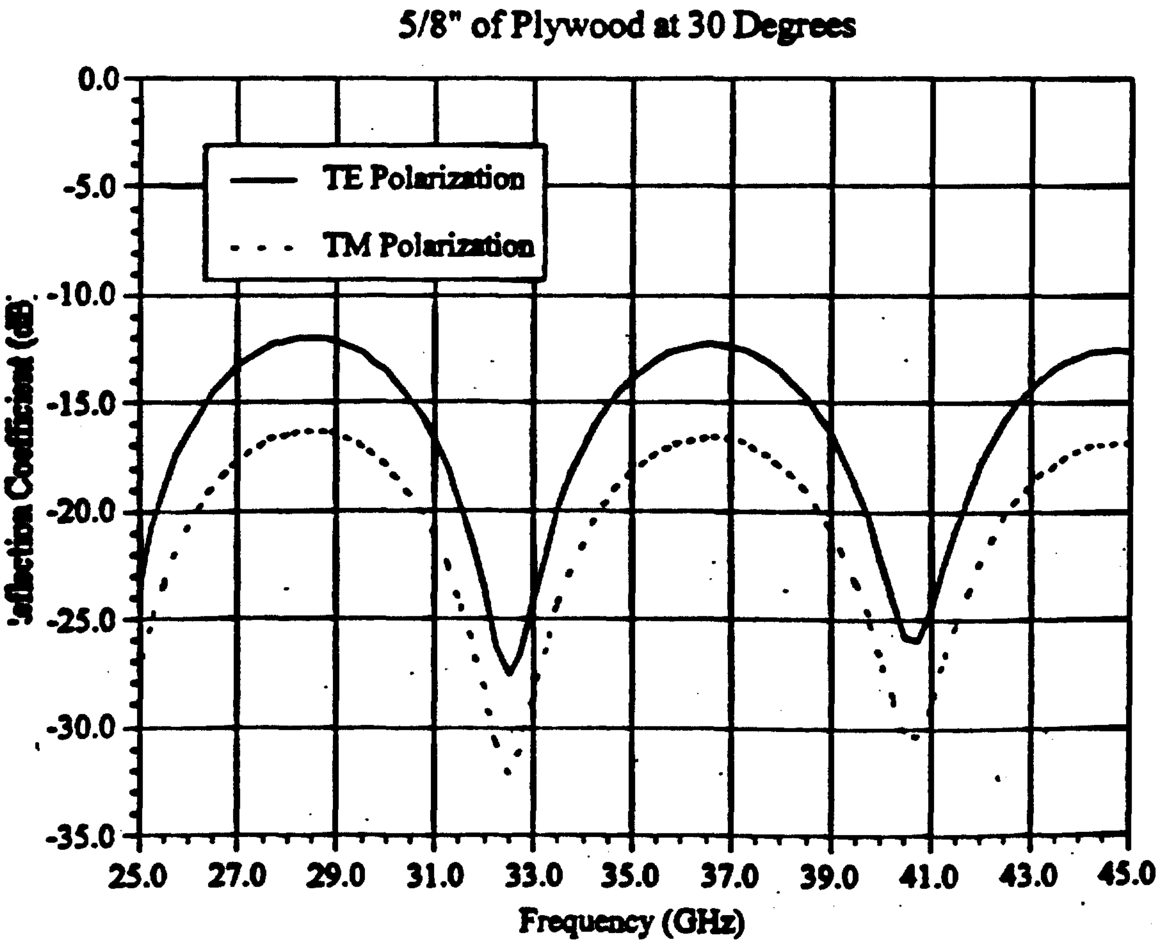


Figure 10. Measured reflection for mirror at a 30° incident angle.





... reflection coefficient for glass and wood at a 30° incident angle

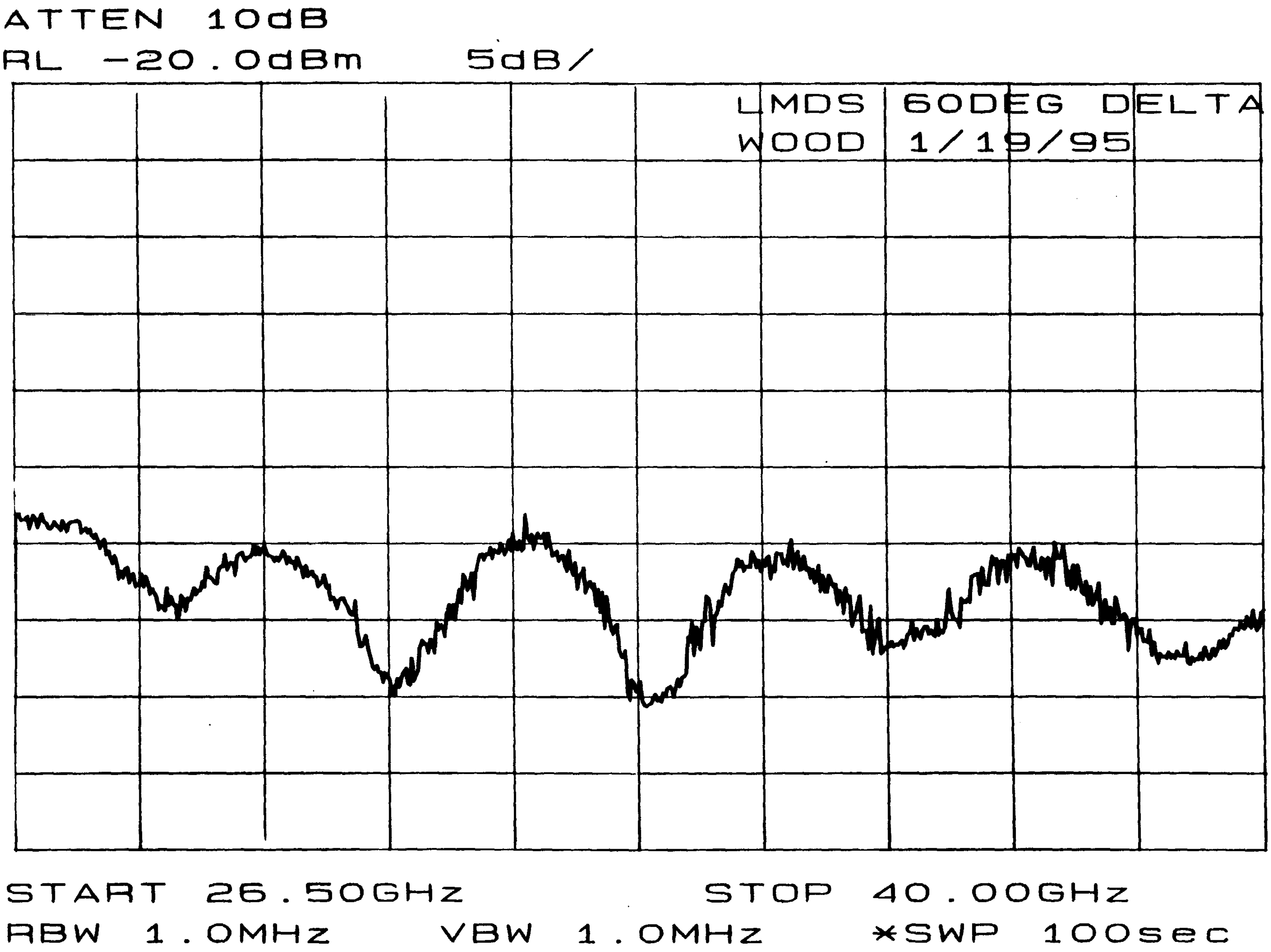


Figure 12. Measured reflection for wood at a 60° incident angle.

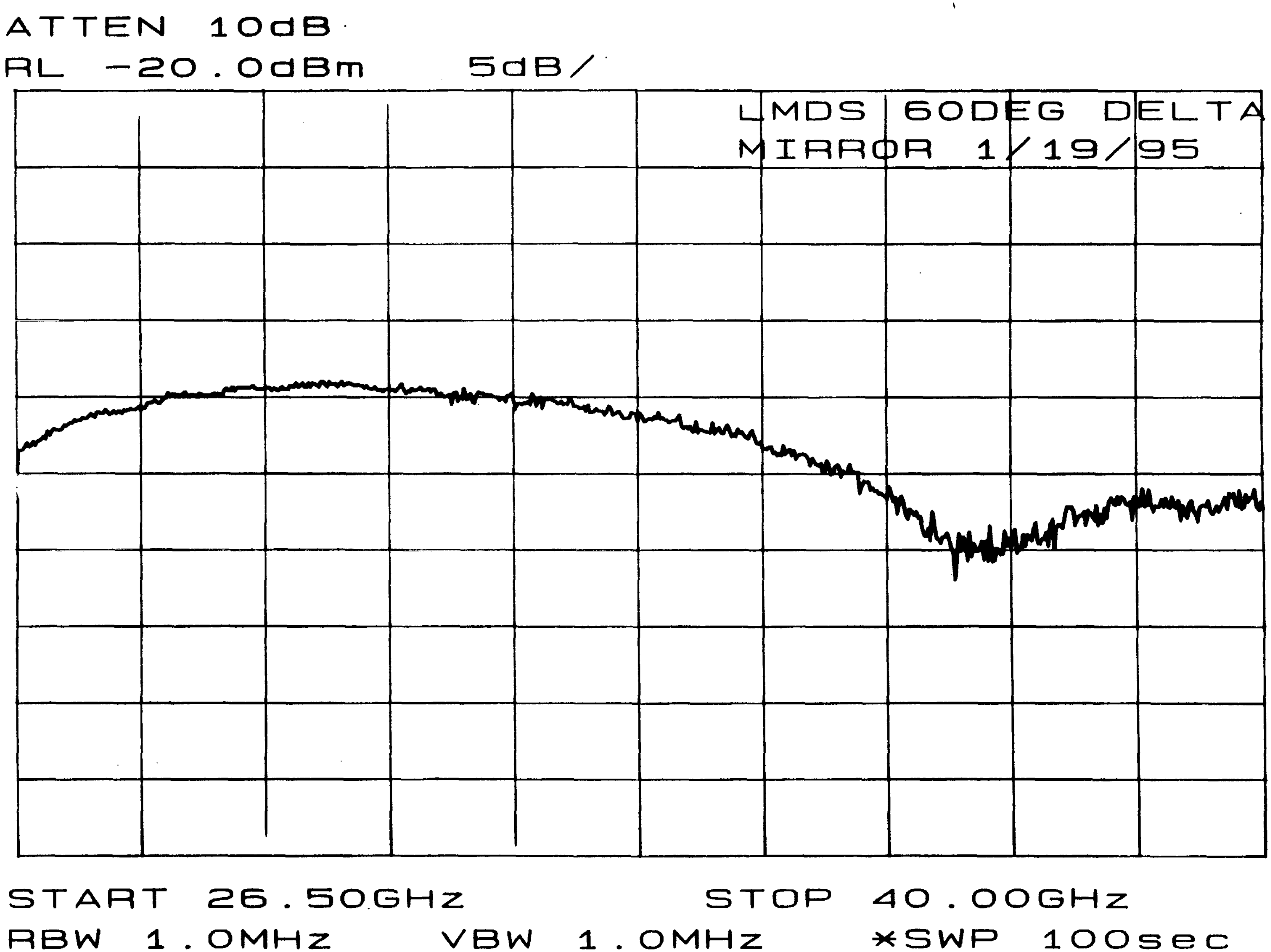
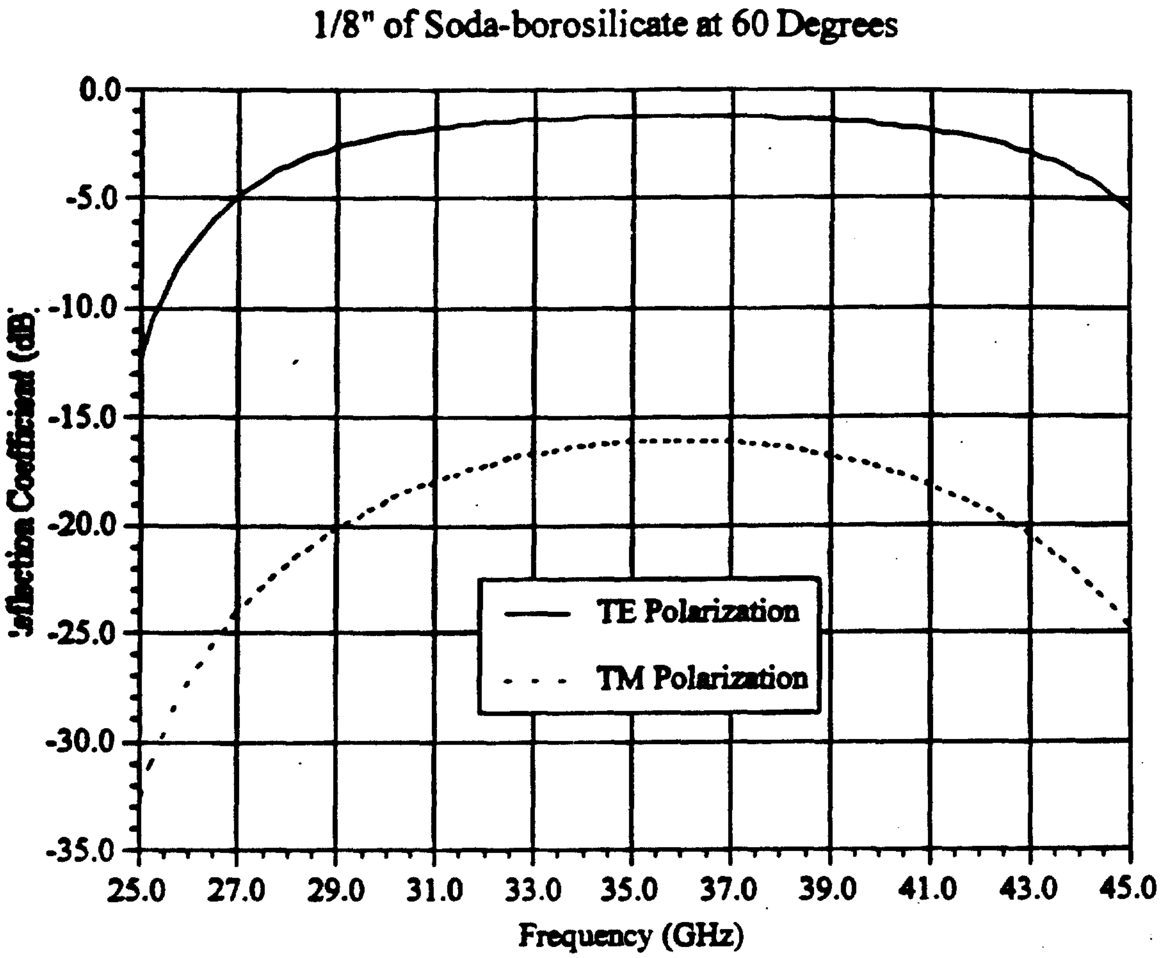


Figure 13. Measured reflection for mirror at a 60° incident angle.



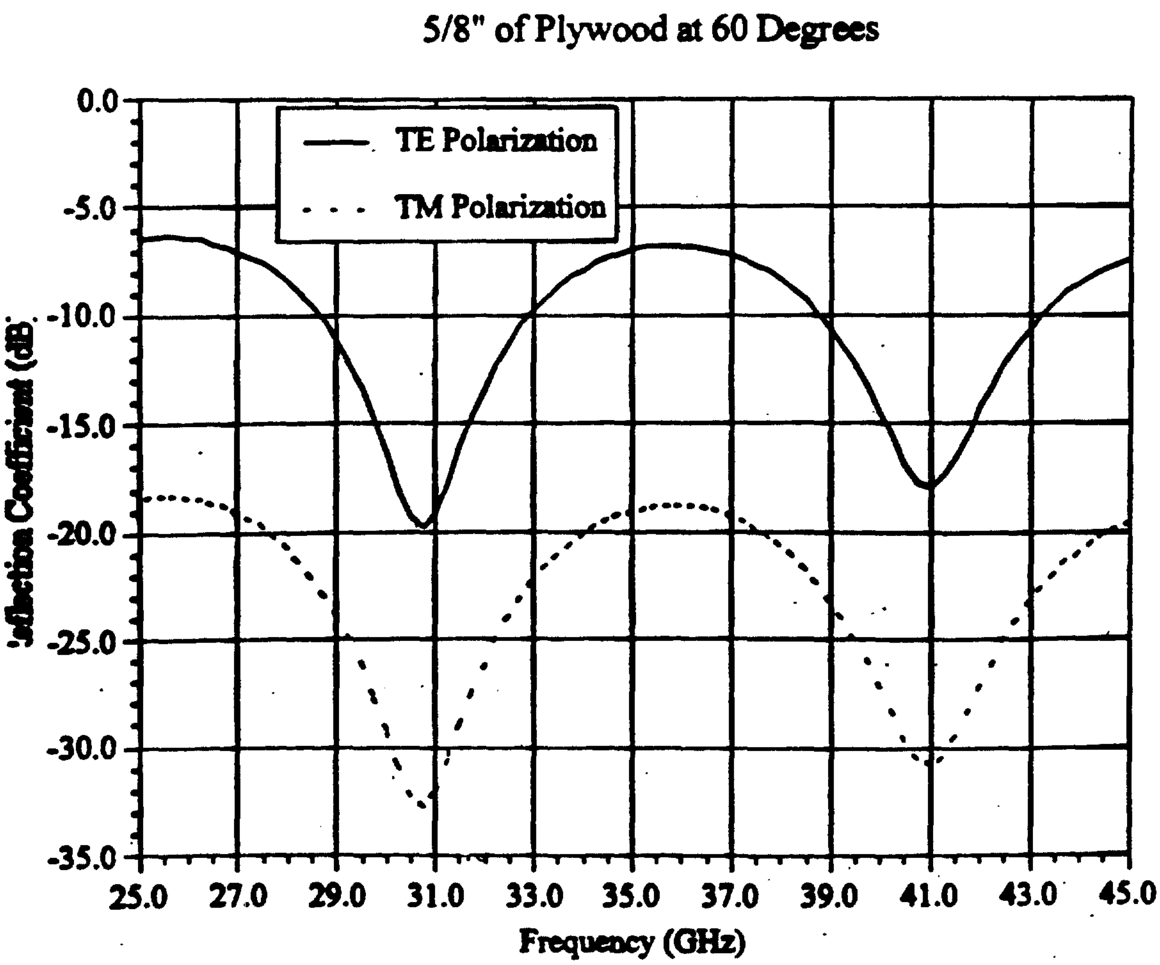


Figure 14. Calculated reflection coefficient for glass and wood at a 60° incident angle.